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Regional Vicarious Gain Adjustment for Coastal VIIRS Products

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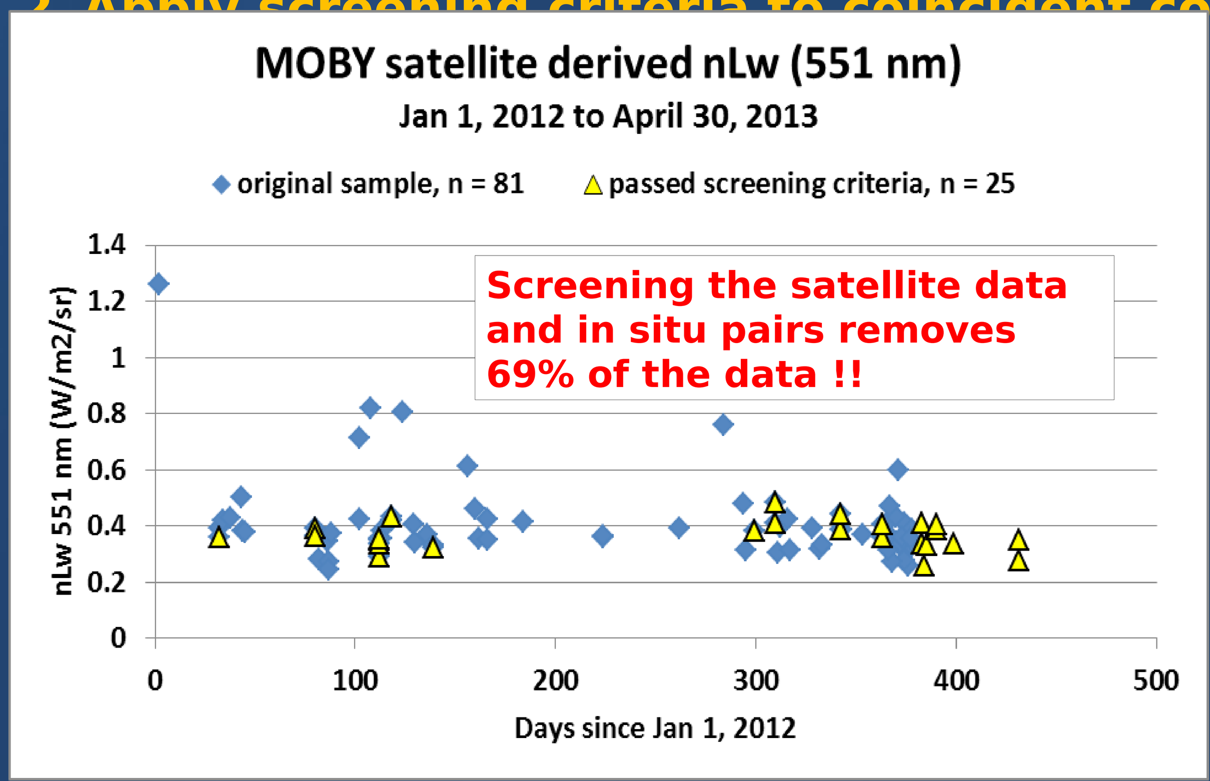
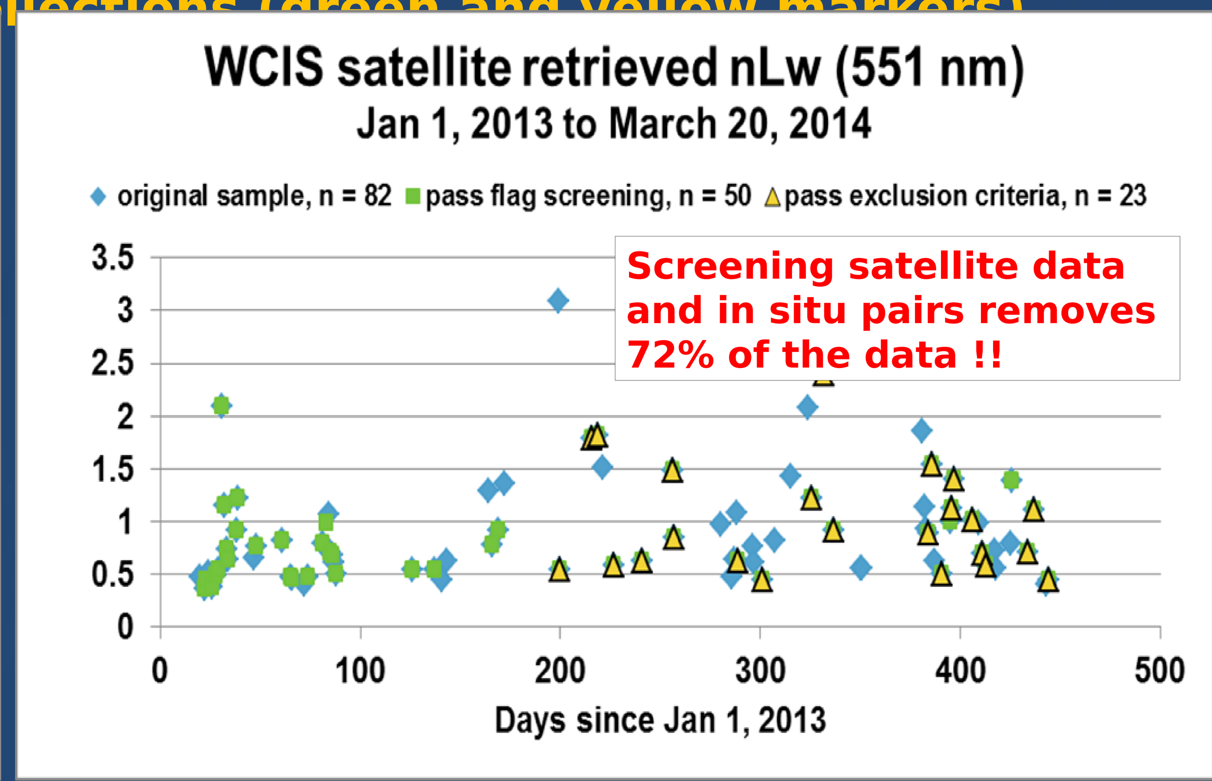
ABSTRACT: As part of the Joint Polar Satellite System (JPSS) Ocean Cal/Val Team, Naval Research Lab - Stennis Space Center (NRL-SSC) has been working to facilitate calibration and validation of the Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color products. By relaxing the constraints of the NASA Ocean Biology Processing Group (OBPG) methodology for vicarious calibration of ocean color satellites and utilizing the Aerosol Robotic Network Ocean Color (AERONET-OC) system to provide *in situ* data (real-time data Level 1.5) , we investigated differences between remotely sensed water leaving radiance and the expected *in situ* response in coastal areas and compare the results to traditional Marine Optical Buoy (MOBY) calibration/validation activities.

An evaluation of the Suomi National Polar-Orbiting Partnership (SNPP)-VIIRS ocean color products was performed in coastal waters using the time series data obtained from the Northern Gulf of Mexico AERONET-OC site, WaveCIS. The coastal site provides different water types with varying complexity of CDOM, sedimentary, and chlorophyll components. Time series data sets were used to develop a vicarious gain adjustment (VGA) at this site, which provides a regional correction of the atmospheric (TOA) spectral offset to compare the standard MOBY spectral calibration gain in open ocean waters.

1. Accumulate coincident matchups (± 3hrs) of satellite and in situ data (blue markers).

2. Apply screening criteria to coincident collections (green and yellow markers).





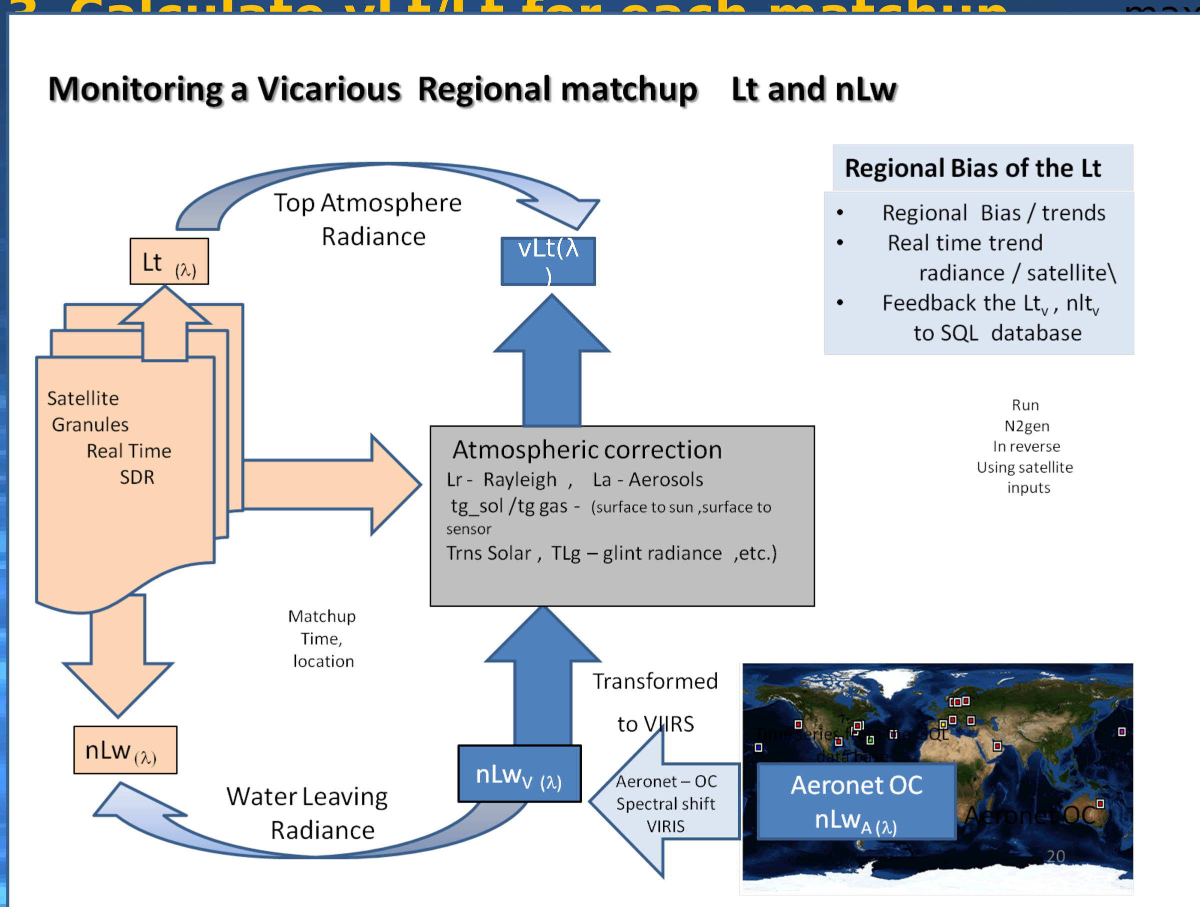
SCREENING CRITERIA IS CRITICAL !

As mission average calibrations have been shown to reach stability after 20 – 40 high quality calibration samples consideration is given to balance the strictness of removal criteria and preservation of sample size (*Franz et. al, 2007, Werdell et al 2007*).

Vicarious calibration
MOBY (*January 2012 to April 2013*)
Satellite constraints: within ±3 hours of over pass and **no** flags allowed on satellite imagery
Exclusion criteria: wind speed must be less than 8 m/s, the maximum aerosol optical thickness (AOT) must be less than 0.2 as measured by the MOBY buoy, the nLw values must be between 0.001 and 3.0, the maximum solar zenith angle = 70 degrees and maximum sensor zenith angle = 56 degrees.

Regional VGA (*relaxed constraints*)
WaveCIS AERONET-OC L1.5 (Jan 2013 to Mar 2014)
Satellite flags: within ±3 hours of overpass, remove atmospheric failure, failure, cloud/ice, high LT, seaice, high satellite zenith angle, high solar zenith angle, epsilon out of range, high glint, max AER iteration, high polarization, moderate sun glint, and coccolithophores *(allows stray light, absorbing aerosols, turbid water)*
Exclusion criteria: wind speed must be less than 8 m/s, the maximum aerosol optical thickness (AOT) must be less than 0.2 as measured by the AERONET, the nLw values must be between 0.001 and 3.0, the maximum solar zenith angle = 70 degrees and maximum sensor zenith angle = 56 degrees.

3. Calculate vLt/Lt for each matchup



Extensively published by NASA's Ocean Biology Program Group (OBPG), the vicarious calibration is an inversion of the forward processing algorithm resulting in a ratio of predicted (vLt) to observed TOA radiance (Lt).

$$\text{gain}(\lambda) = vLt(\lambda) / Lt(\lambda)$$

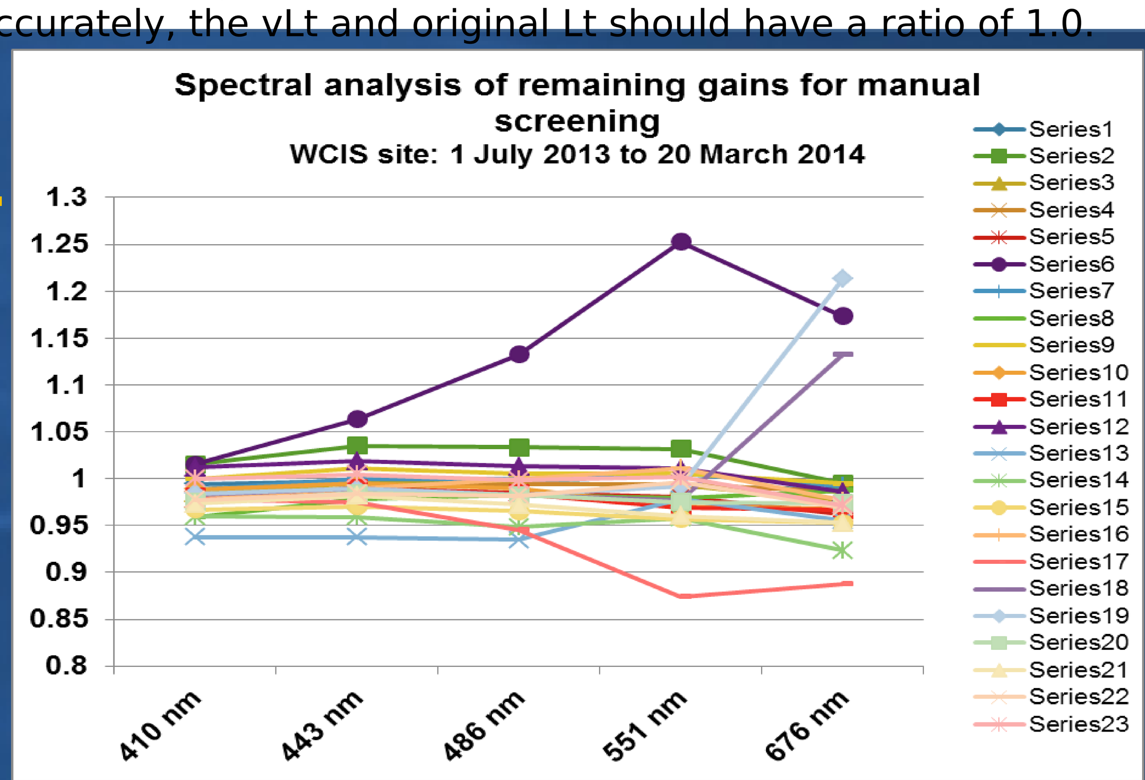
APS processing employs:

- standard atmospheric correction of Gordon/Wang
- Stumpf NIR iteration
- Initial processing assumes perfect sensor calibration (unity gains)
- save the atmospheric components (Lr, La, transmittances, polarization correction, etc.) and pointing-angles
- nLw from the *in situ* sensor is run through the inversion where the atmospheric components are added back creating an expected Lt from the view of the VIIRS (vLt(λ))

In a perfect system in which all components are computed accurately, the vLt and original Lt should have a ratio of 1.0.

4. Plot spectral gains and remove anomalies.

This leads to removal of Series 6, 17, 18, and 19.



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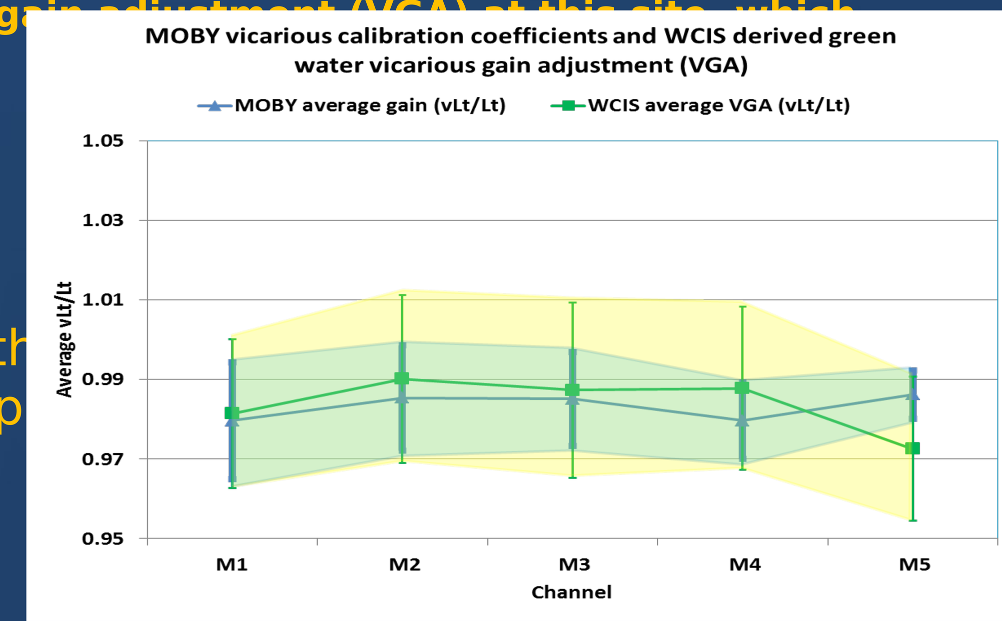
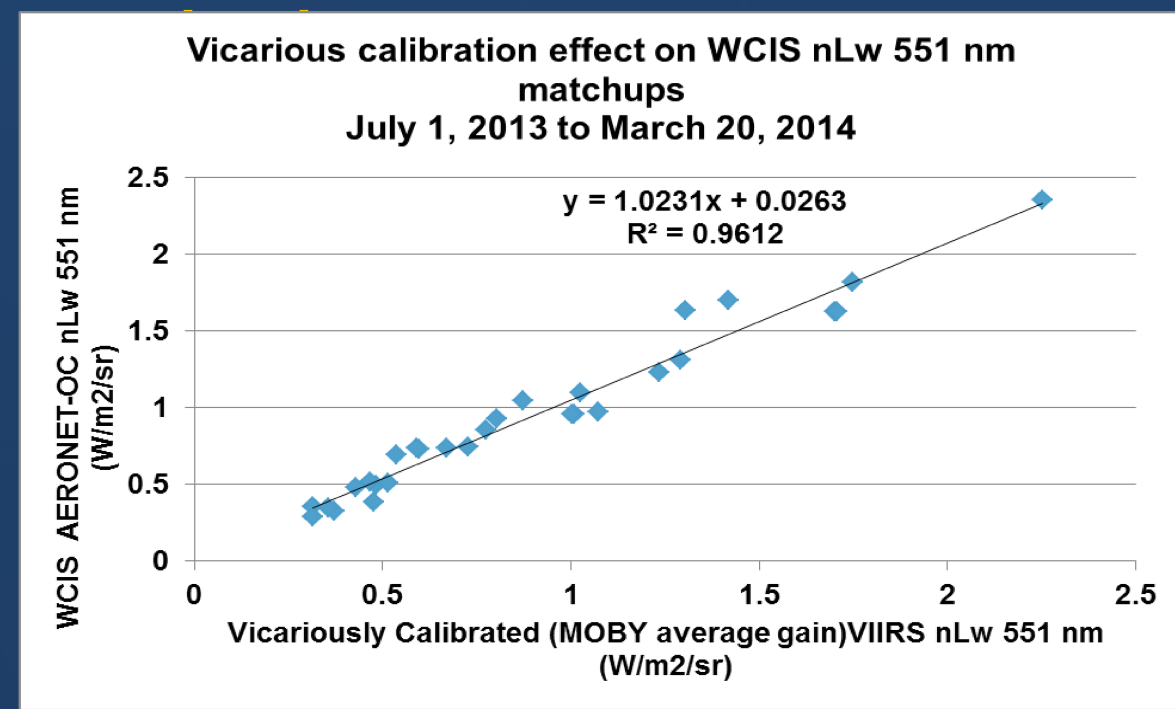
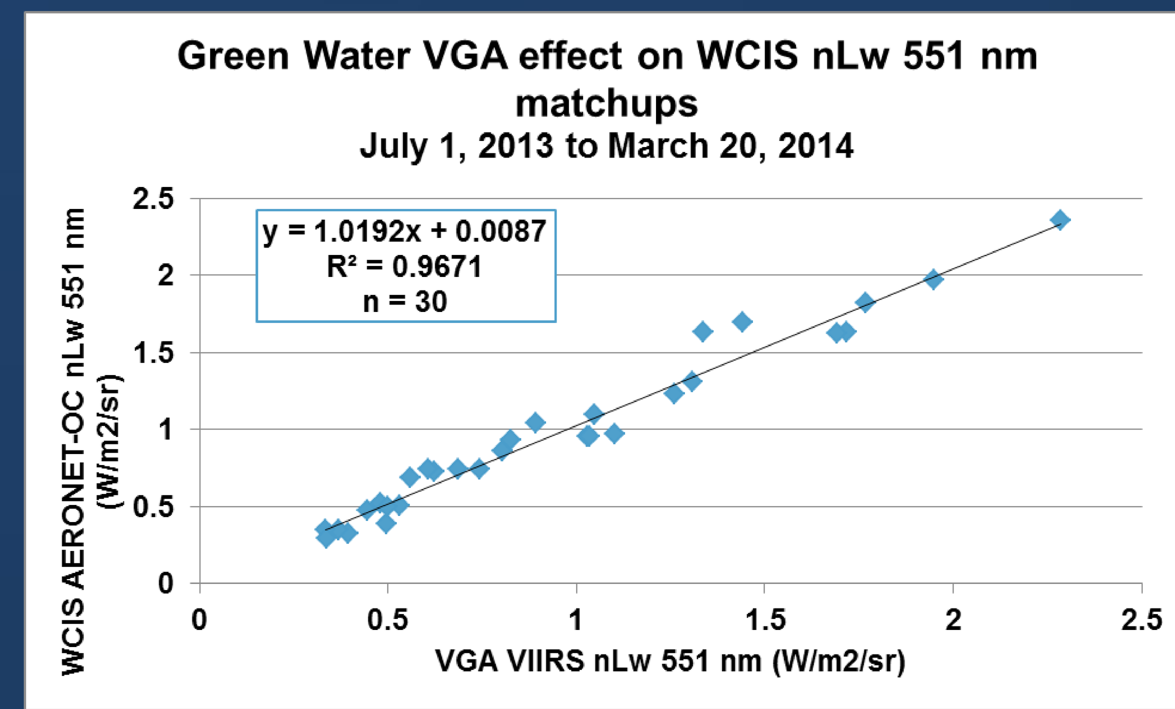
5. Calculate an average gain for each site: MOBY vicarious calibration and WCIS VGA.

Although there is no statistical difference between the vicarious calibration and VGA gains, the MOBY site provides less uncertainty.



6. Apply Vicarious calibration and VGA using APS and look at effects on the nLw



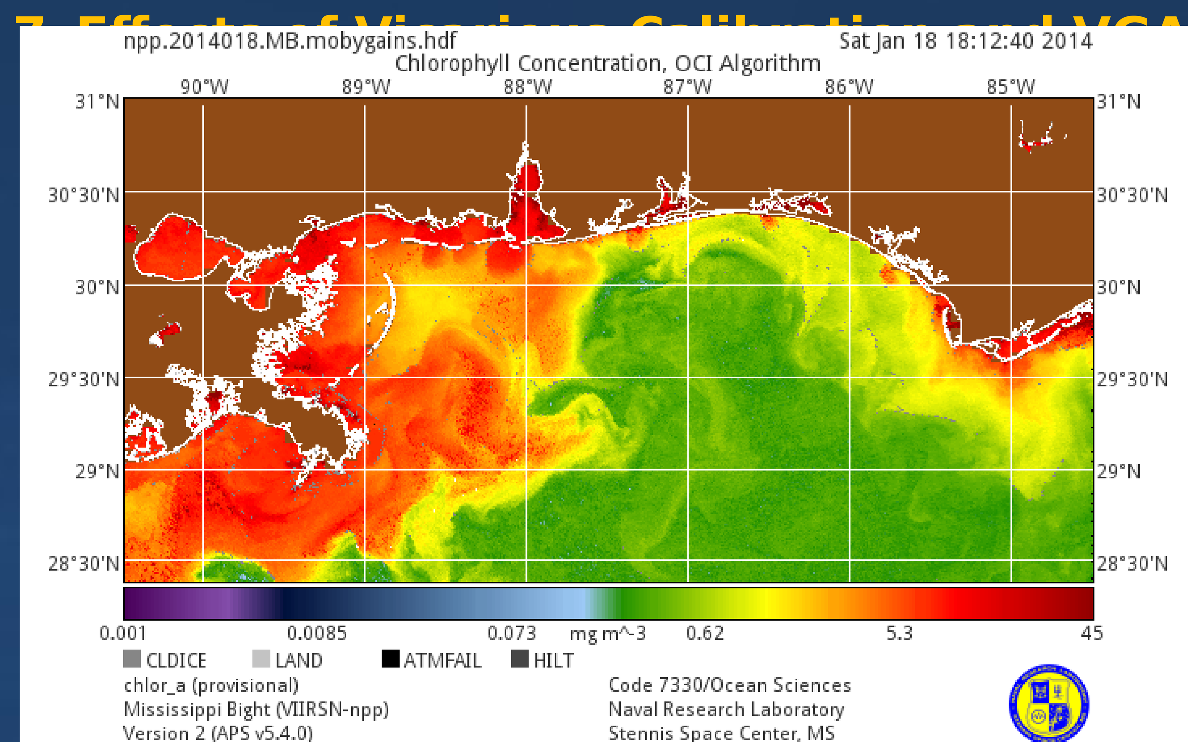


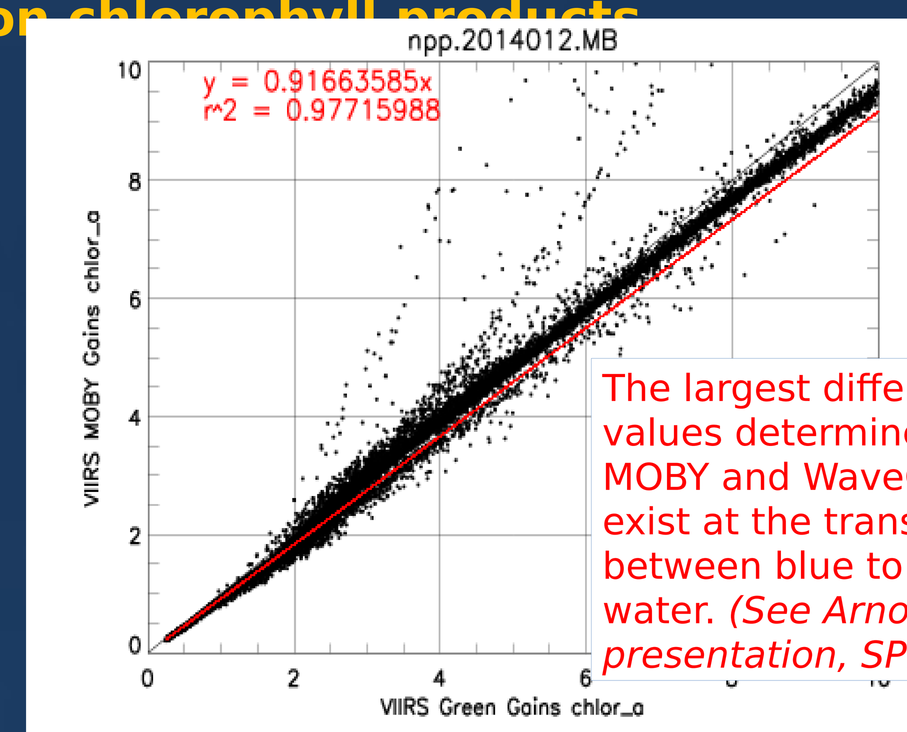
gain set	wavelength	regression equation	R^2
MOBY gains	nLw 410 nm	y = 0.6151x + 0.1962	R^2 = 0.4005
WCIS gains	nLw 410 nm	y = 0.6894x + 0.1915	R^2 = 0.4213
MOBY gains	nLw 443 nm	y = 0.8955x + 0.1248	R^2 = 0.7199
WCIS gains	nLw 443 nm	y = 0.96x + 0.0819	R^2 = 0.7745
MOBY gains	nLw 486 nm	y = 1.083x + 0.025	R^2 = 0.9096
WCIS gains	nLw 486 nm	y = 1.105x + 0.0215	R^2 = 0.9317
MOBY gains	nLw 551 nm	y = 1.0231x + 0.0263	R^2 = 0.9612
WCIS gains	nLw 551 nm	y = 1.0192x + 0.0087	R^2 = 0.9671
MOBY gains	nLw 671 nm	y = 0.8689x + 0.0141	R^2 = 0.9337
WCIS gains	nLw 671 nm	y = 0.8853x + 0.0389	R^2 = 0.9433

The table to the left summarizes the regression statistics calculated for the MOBY and WaveCIS gains applied during image processing on the nLw retrievals by the satellite (x) compared to the *in situ* (y) as illustrated in the figures above. The results show minor improvements for using the green water VGA at all wavelengths except 486nm however, the slopes are not statistically different.

Recall: slopes closer to 1 indicate better calibration while higher r2 indicates better statistical fit of the regression

7. Effects of Vicarious Calibration and VGA on chlorophyll products





The largest differences in chl values determined with MOBY and WaveCIS gains, exist at the transitions between blue to green water. *(See Arnone presentation, SPIE, 2014)*

8. Conclusions:

- The procedure addresses selection criteria for optimizing data quality in a near real-time situation, allowing for vicarious calibration and regional VGA to be established for each of the VIIRS visible channels.
- Assembling an optimum data set for determining average gains is time consuming and excludes considerable data: 69% for MOBY and 72% for WaveCIS site
- The standard deviation of the adjustment gains was deemed acceptable and the screening procedure is critical to determining the adjustment.
- Due to the uncertainties in the vicarious calibration and VGA processes there was not a statistically significant difference in the blue water (g01) and green water (g02) gains, however; as expected, the blue water gains exhibit lower standard deviations per channel.
- Optimizing selection of matchup points provides a strong relationship between satellite and *in situ* nLw(λ) and chl for both gain sets, MOBY and WaveCIS.

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